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Title: Not one more US tokamak

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The tokamak has been the primary magnetic fusion confinement platform in the USA since the Model C Stellarator was converted to the Symmetric Tokamak in 1970. The tokamak concept holds records for the best fusion performance parameters of any MFE concept, to-date. Presently, the only mid-scale operating US DOE magnetic fusion confinement facility, is the DIII-D tokamak at General Atomics in San Diego (at least until NSTX-U repairs are completed). But it has been more than thirty years since DIII-D was first put into operation. There is not a single new next-generation DOE-funded mid-scale (or larger) magnetic fusion confinement facility planned in the USA for the next 10 years. *When and if there is a next generation new US domestic confinement machine funded by DOE, it should not be a tokamak.*

Why are we, dyed-in-the-wool (also somewhat long-in-the-tooth) plasma fusion researchers, who have worked on many tokamaks, against building any future tokamaks? In short, because the tokamak concept has at least two major flaws… the lack of a sufficiently efficient current drive technique, and the existence of disruptions of the plasma current. Disruptions are the show-stopper. Disruption of the toroidal plasma current in a tokamak causes three immediate problems: 1) Generation of large electromagnetic forces on machine components. 2) Requirement to uniformly radiate the kinetic energy of the plasma (100's of MJ in ITER), and 3) generation of Mega-amperes of relativistic (10's of MeV) electrons …. so-called runaway electrons. The capability to eliminate all forms of disruptions has never been demonstrated in any existing tokamak. Even though scientists propose staying away from "dangerous" operating points (high beta-poloidal, low-q edge, etc.), in fact there is no "safe" operating regime (disruption-free) for a tokamak….impurity bloom or density limit disruptions can always occur when a small chunk of eroded/redeposited material falls into the plasma from the wall. This is expected to be a more serious issue with future long-pulse operation. The proposed solution for ITER, is that since disruptions cannot be completely Prevented or Avoided, they must be Mitigated with 100% certainty. The presently proposed mitigation technique, Shattered Pellet Injection, has finite response time once requested (triggered), and has not been proven to mitigate the three problems (listed above) simultaneously. In fact, successful mitigation of one of the three problems can result in worsening of the others. False positive mitigation attempts (ie. Mitigations you didn't really need) also have adverse consequences on NBI and pumping systems as well. But failed mitigation of a full energy disruptions on ITER can be expected to result in armor melting and water leaks, in as few as a single occurrence. Basically, the existence of 10 MA of relativistic runaway electrons in ITER, will become a textbook example of what the world's largest and most powerful uncontrolled e-beam welding machine on the planet would do to tokamak armor.

Tokamak programs of the world ASSUME that they will solve the disruption problem through the use of dynamic control systems. However, learning to do this at ITER-scale will be a costly, daunting, and unforgiving task. Is there a better way? Yes, by passively engineering the problem out of the design of the confinement device. Don't allow the free energy source (of the plasma current) to exist in the first place. Build stellarators! And by the way, that also solves the problem of inefficient tokamak current drive systems. Current drive efficiency is such a problem in fact, that present DEMO designs are forced to assume a pulsed tokamak reactor scenario. Stellarators don't need current drive systems either.

Based on the recent highly successful Wendelstein 7-X operation in Germany (a ~$1.5 B facility), and computer design codes, the next US confinement machine(s) should be an optimized stellarator variant. Multiple ideas exist for mid-scale stellarator experiments, which are scientifically interesting, and push the world's knowledge envelope, even if they are not in the superconducting long-pulse $B class of experiments.